

REVIEW OF INTERNATIONAL EXPERIENCE INTEGRATING VARIABLE RENEWABLE ENERGY GENERATION

APPENDIX A: DENMARK

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Preface

The Public Interest Energy Research (PIER) Program supports public interest energy research and development that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

The PIER Program, managed by the California Energy Commission (Energy Commission) conducts public interest research, development, and demonstration (RD&D) projects to benefit the electricity and natural gas ratepayers in California.

The PIER program strives to conduct the most promising public interest energy research by partnering with RD&D organizations, including individuals, businesses, utilities, and public or private research institutions.

PIER funding efforts are focused on the following RD&D program areas:

- Buildings End-Use Energy Efficiency
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- Renewable Energy Technologies
- Transportation

Review of International Experience Integrating Variable Renewable Energy Generation, Appendix A: Denmark is the final report for a subtask of Task 3 for the PIER Intermittency Analysis Project (IAP), contract number 500-02-004, work authorization number MR-017, conducted by the IAP team comprised of the California Wind Energy Collaborative, Exeter Associates, BEW Engineering, Davis Power Consulting, and GE Energy Consulting (with assistance from AWS Truewind, National Renewable Energy Laboratory (NREL), Oak Ridge National Laboratory (ORNL), and Rumla Consulting). The information from this project contributes to PIER's Renewable Energy Technologies program.

For more information on the PIER Program, please visit the Energy Commission's website at www.energy.ca.gov/pier or contact the Energy Commission at (916) 654-5164.

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Abstract

This report summarizes the experience in the United States and internationally through 2006 with integrating variable renewable energy generation, primarily wind generation, and discusses potential operating and mitigation strategies for incorporating variable renewable energy generation. Initially, wind development in Denmark and Germany, consisted of smaller but numerous wind projects interconnected to the distribution grid, in contrast with larger, utility-scale wind projects interconnected to the transmission grid in the United States. The differences between Europe and the United States are starting to narrow as development of variable renewable energy generation (e.g. wind and solar) increases and as wind development takes place in more countries. In addition, as more utility-scale wind projects emerge, more countries are relying on common strategies, such as grid codes, to help integrate variable renewable energy generation. This report is a part of the Intermittency Analysis Project (IAP), a comprehensive project aimed at assessing the impact of increasing penetration of variable renewable energy generation in California. A review of the international experience will provide perspective and insight to the IAP analysis team on various techniques for managing intermittency.

Keywords: interconnection, transmission service operator, turbines, variable renewable energy generation, wind forecasting, wind integration.

1.0 Denmark Profile

By the percentage of energy demand met by wind, Denmark is the global leader in wind power. By the end of 2005, 18.5% of the energy generated in Denmark was from wind power, and wind capacity had reached 3,128 MW, including 424 MW of offshore wind capacity (Lemming et al. 2006). In 2005, 18 new turbines with a combined capacity of 22.2 MW were installed while 129 old turbines with a combined capacity of 18.2 MW were decommissioned (Moller 2006b). As evident by market activity in 2005, Denmark's wind developers are focused on repowering and decommissioning aging units rather than the development of new, larger wind parks.

A majority of the wind power development occurs in Western Denmark, accounting for about 2,400 MW of the 3,128 MW of the installed wind capacity in Denmark. The impacts of wind are more pronounced in Western Denmark and will therefore be the primary focus of this section. Overall, the total capacity in Western Denmark is 7,488 MW, which is produced by a combination of central power plants, combined heat and power (CHP), and wind turbines (see Table 1). In 2004, wind power accounted for 23% of the total energy consumed in the region (Agersbaek 2005).

Table 1. Total production capacity in Western Denmark as of January 1, 2005

Total Production Capacity	7,488 MW
11 Central Power Plants	3,516 MW
558 Combined Heat and Power	1,593 MW
4,161 Wind Turbines	2,379 MW

Source: Agersbaek, Gitte. (2005). *Wind Integration in Western Denmark*. Presentation for the Utility Wind Interest Group's Wind Integration and Interconnection Workshop, April 14, Minneapolis, Minnesota

The addition of not only wind generation but also combined heat and power (CHP) plants transformed Denmark's power system from a central grid in the 1980s to a distributed grid by 2000 (see Figure 1). By 2003, generating capacity had grown to double peak electricity consumption (Eltra 2004a).

Figure 2 illustrates the sharp increase in CHP and wind generating plants in Denmark. In 1996, the Danish government set a goal of 1,500 MW of wind by 2005, a level that was surpassed by 2000. The Danish government has set a new goal of 5,500 MW of wind, which is equivalent to 50% of the total electricity demand in Denmark (Gilecki and Poling 2005).

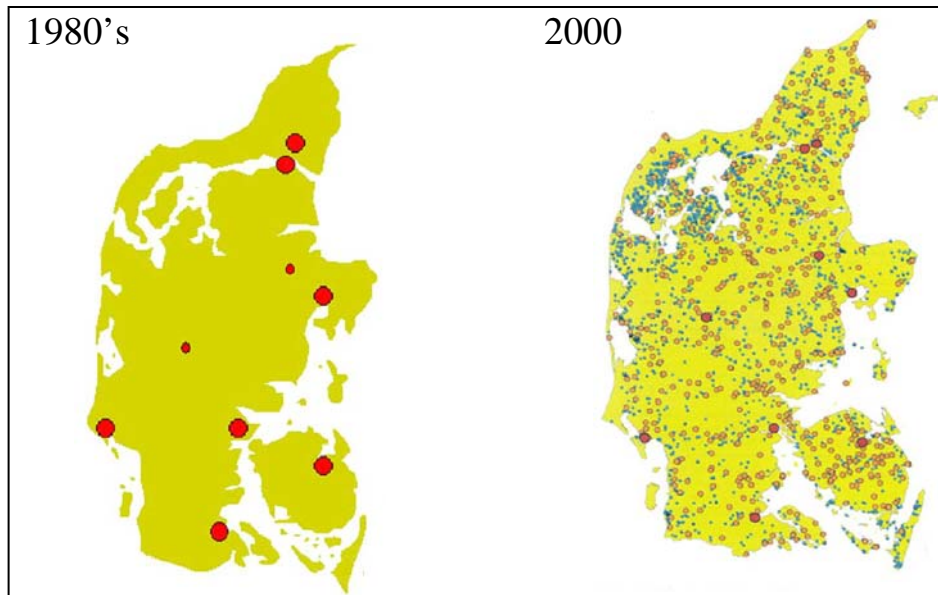


Figure 1. Denmark's electric grid, Then and Now

Source: Agersbaek, Gitte. "Wind Integration in Western Denmark." Minneapolis, Minnesota: Presentation for the Utility Wind Interest Group's Wind Integration and Interconnection Workshop, April 14, 2005

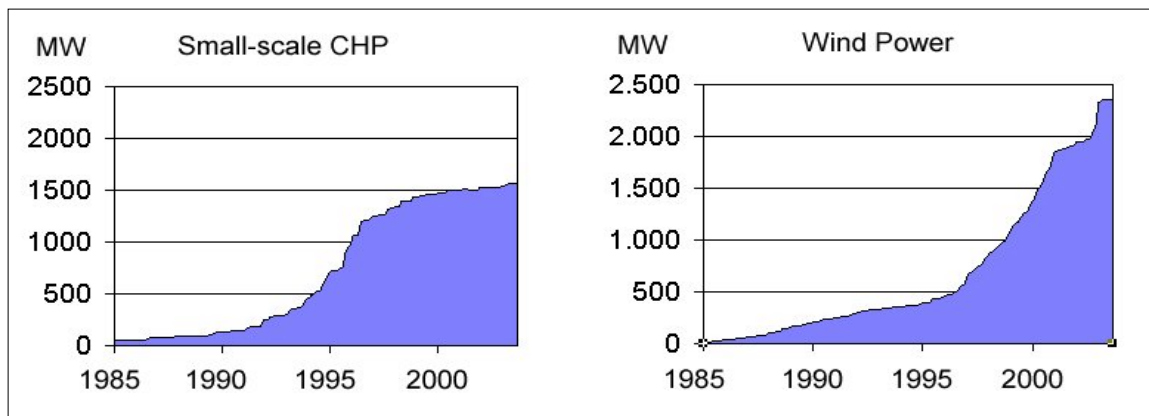


Figure 2. The growth of small-scale CHP and wind in Denmark

Source: Agersbaek, Gitte. "Wind Integration in Western Denmark." Minneapolis, Minnesota: Presentation for the Utility Wind Interest Group's Wind Integration and Interconnection Workshop, April 14, 2005.

Table 2 provides data on consumption, production and generation from CHP and wind units in the Eltra service area, the Transmission Service Operator (TSO) in Western Denmark. Wind and CHP combined account for about 50% of the energy used for consumption.

Table 2. Key figures for Eltra

	1999	2000	2001	2002	2003	2004
Consumption TWh	20.5	20.7	20.9	20.9	21.0	21.3
Production TWh	22.6	21.0	23.1	23.5	27.4	24.7
CHP TWh	6.4	6.2	6.8	6.7	6.8	6.8
Wind Power TWh	2.4	3.4	3.4	3.8	4.4	4.9
Wind power in % of consumption	11.7%	16.4%	16.3%	18.2%	21.0%	23.0%
Exchange TWh	- 2.1	- 0.3	- 2.2	- 2.6	- 6.3	- 3.4

Source: Agersbaek, Gitte. "Wind Integration in Western Denmark." Minneapolis, Minnesota: Presentation for the Utility Wind Interest Group's Wind Integration and Interconnection Workshop, April 14, 2005

Almost all of the wind turbines in Western Denmark are under 1 MW, relatively small compared to the multi-megawatt wind turbines installed in other parts of the world. Much of the wind turbines were developed through cooperatives of landowners or farmers, each owning a small number of turbines. As shown in Figure 3, there were 4,175 wind turbines in Western Denmark as of March 2004, amounting to 2,374 MW. The average capacity of each wind turbine is 570 kW.

2.0 Denmark's Wind Resource

Denmark's wind resources have a slight diurnal variation in the winter, and that variation is more pronounced in the summer (Holttinen 2004). Wind is somewhat correlated with seasonal demand in Denmark. The minimum load for Denmark is 1,150 MW, which usually occurs on a summer weekend. The maximum load is typically during the middle of a week in the winter at about 3,800 MW. In Denmark, it is typically windier in the winter months, which corresponds to the time when maximum load occurs. There is less wind in the summer months when Denmark usually experiences its minimum load time period. For example, the average capacity factor of wind in the winter of 2000 is 33.5% compared to 17.9% in the summer (Agersbaek 2005).

Wind production in Denmark varies more hourly than minute-to-minute. From a study on wind power production in Denmark for the years 2000 and 2001, it was found that for 15-minute variations, production from wind could vary by 8.4% of capacity. In 2000, the maximum hourly variations were up 20.1% and down 23.1% of installed capacity (Holttinen 2004).

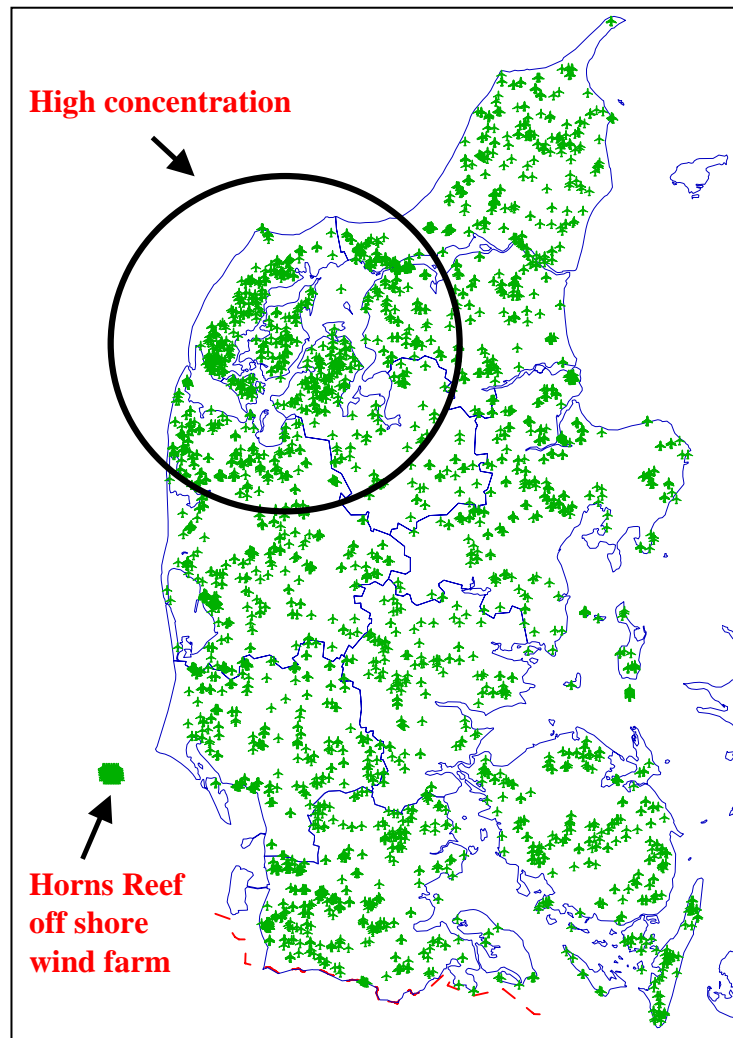


Figure 3. Wind turbine installations in Denmark

Source: Agersbaek, Gitte. "Wind Integration in Western Denmark," Minneapolis, Minnesota: Presentation for the Utility Wind Interest Group's Wind Integration and Interconnection Workshop, April 14, 2005.

3.0 Drivers to Wind Development in Denmark

Public policy has been a key factor in the growth of wind power in Denmark. From 1979 to 1989, Denmark had a sliding scale investment subsidy for wind turbines, beginning at 30% of the cost of wind turbines, and declining to 10% by 1989. In 1981, government energy taxes were partially offset by a two-part subsidy for wind energy producers. The first part was a carbon dioxide based tax system that provided a subsidy of 1.6 cents per kilowatt-hour, and the second part was a production incentive for private producers of 2.8 cents per kilowatt-hour. In addition, the Danish Wind Turbine Guarantee was established in 1990 that established long-term financing for large wind projects that used Danish-made turbines.

Feed-in tariffs also were a major contribution to the advancement of the wind energy industry in Denmark. The network operator closest to the wind farm was obligated to connect the wind farm to the grid and purchase the wind energy at a specified tariff (Blunden 2004). Beginning in 1992, the government required that all utilities purchase renewable energy from private producers for a fixed rate of 70 to 85% of the retail price of energy, with the price varying by location depending on average electricity rates (Gilecki and Poling 2005). Denmark planned to scale back its feed-in tariff in favor of a market based on tradable green electricity certificates, only to abandon the concept before it was formally launched, thus lending instability to what has been a very stable policy framework for wind in Denmark. As a result, only four wind turbines were installed in 2004, for a total capacity of 5.6 MW, the lowest since the early 1980s. Denmark's current wind policy focuses on a five-year repowering program through 2009 for turbines up to 450 kW in capacity, replacing 350 MW. In 2005, 129 wind turbines representing 18.2 MW were removed and replaced by 18 new turbines with a total capacity of 22.2 MW. Over the last five years, 1600 older wind turbines have been decommissioned, leaving 5,293 still in operation (Moller 2006b). Denmark will also hold an auction to add 200 MW each to two existing offshore wind projects, although not until 2008 at the earliest (Moller 2005a).

Denmark's Parliament made other significant changes to Denmark's energy policy in 2004. The changes included the following:

- Subsidies for CHP units were changed and most CHP units have to participate in the electricity market. CHP units over 10 MW have to be in the market by January 2005, while CHP units between 5 and 10 MW had two years to be in the market. Under market terms, CHP units can generate electricity when the market price for electricity is high enough that the combined production of electricity and heating can result in a profit for the CHP unit. Otherwise, the heating requirement for CHP units is met by peak-load boilers. In all, about 80 CHP units meet these conditions, representing 1,020 MW. Another 480 CHP units, amounting to 526 MW, are exempt from market requirements and maintain priority grid access.
- Denmark's government took over the two TSOs, Eltra and Elkraft, in 2005 to form Energinet dk. The Danish government also has a preemptive right to acquire the 132-150 kW grids (Eltra 2004a).
- Two more offshore wind projects of 200 MW each are to be developed.

4.0 The TSOs in Denmark and International Transmission Interconnection

Western Denmark is interconnected with the Union for the Coordination of Transmission of Electricity (UCTE). The UCTE area encompasses and interconnects a majority of the mainland of Europe (Eriksen and Hilger 2005). Eastern Denmark region only has a small part of the installed wind capacity in Denmark. That region is part of Nordel, an organization of TSOs in the Nordic region. Nordel is an international organization created to facilitate cooperation among the TSOs of Finland, Sweden, Norway, Denmark, and Iceland. Iceland is part of Nordel, but is not interconnected with the other Nordic countries. Both Nordel and UCTE have the responsibility for maintaining security and reliability of the electricity system.

Energinet.dk participates in Nordpool, a multinational power exchange market. Because Western Denmark is not interconnected with Eastern Denmark, both regions form different pricing zones in Nordpool. However, both regions are indirectly connected through interconnections Germany and Sweden (Eltra 2004b). In Nordpool, Denmark is between hydro-dominated Sweden and Norway and coal-dominated Germany, and therefore, power prices in Denmark depend in part on what is happening in Norway, Sweden, and Germany.

Much of the wind capacity in Denmark is connected to the distribution system at levels below 100 kV (see Table 4). Because the transmission operator cannot necessarily “see” the distributed generation, close cooperation between the transmission operator and the distribution utility is required

Table 3. Production capacity by voltage level within Western Denmark as of January 2005

Designation	Voltage Level	Generation
Energinet.dk	400 kV	Four primary power stations (1,488 MW)
Transmission Company	150 kV	Five primary power stations (1,914 MW)
Distribution	60 kV	80 wind turbines (160 MW) 16 local plants (589 MW) (18 generators)
Distribution	10-20 kV	34 wind turbines (41 MW) 543 local plants (1,093 MW) (734 generators) 4,047 wind turbines (2,179 MW) 1,000 PV units (2 MW)

Source: Erikson, Peter Borre; Ackerman, Thomas; Abildgaard, Hans; Smith, Paul; Winter, Wilhelm; and Garcia, Juan Ma Rodrigues. “System Operation with High Wind Penetration: The Transmission Challenges of Denmark, Germany, Spain and Ireland.” *IEEE Power and Energy*, November/December 2005, pp. 65-70

Denmark has strong transmission ties with its neighbors, greatly aiding wind integration (see Figure 4). There are about 712 kilometers of 400 kilovolt lines and 1,739 kilometers of 150 kilovolt lines connecting Denmark to Norway and Sweden by high voltage direct current (HVDC). All told, Denmark has connections to neighboring countries of about 3,000 MW. Specifically, Norway has the capacity to import 1,000 MW and export about 950 MW to Denmark, while Sweden can import 460 MW and export 490 MW to Denmark. In addition, Denmark is interconnected with Germany, and Germany has the capacity to import 800 MW and export 1,200 MW (Eriksen and Hilger 2005).

Norway (HVDC "Skagerrak"):

Capacity, import: 1,000 MW

Capacity, export: 950 MW

Sweden (HVDC "KontiSkan"):

Capacity, import: 460 MW

Capacity, export: 490 MW

Germany (AC):

Capacity, import: 800 MW

Capacity, export: 1,200 MW



Figure 4. Interconnecting western Denmark with Scandinavia and Europe

Source: Agersbaek, Gitte. "Wind Integration in Western Denmark." Minneapolis, Minnesota: Presentation for the Utility Wind Interest Group's Wind Integration and Interconnection Workshop, April 14, 2005

The international interconnections are advantageous to Denmark, as it gives the system operators additional resources to use to compensate for any imbalances within the electricity system. For example, if there is an oversupply of electricity generated in Denmark, then the excess can be transmitted into the Nordic market, including the countries of Norway, Sweden, and Finland. Other countries can purchase the excess energy generated in Denmark, or the excess energy can be stored in hydro facilities (Gul and Stenzel 2005). Also, if there is a shortage of energy generation in Denmark, system operators can purchase electricity from the neighboring countries.

5.0 Market Operations

The hourly production schedules are created twenty-four hours before the time of operation to make balancing trades on the Elspot. The Nordpool Elspot is a day-ahead market where generators and consumers submit their bids by noon the day before. All participants in Elspot have equal access to the transmission grid based on a tariff. The market price is set where supply equals demand. If there is no transmission congestion, then there will be one market price. If there is transmission congestion, then the market will split into submarkets, with the constrained areas setting their own price.

In Denmark, Energinet.dk informs the demand side three months in advance of the hourly percentage of priority production of wind and CHP that consumers must purchase. The differences between the three month and 12 to 36 hour forecast are balanced in Nordpool. Energinet.dk determines an expected hourly value for wind and CHP that is not in the market, then subtracts that from the load forecast. Energinet.dk trades the difference, be it positive or negative, as a flat hourly block at Nordpool, when Energinet.dk is either a seller at price zero or a buyer at maximum price. Imbalances between schedules and deliveries are balanced in the Nordpool regulating market, and prices bid into that market determine the imbalance price. Denmark uses a two-price imbalance system, where a market participant will pay imbalance charges if their hourly imbalance is in the same direction as the system imbalance for that hour. Conversely, a market participant is paid the spot market price for that hour (i.e., the hourly price of Nordpool's regulating market) if the imbalances are in the opposite direction of the system imbalance. A market simulation of Western Denmark in 2001 estimated that balancing costs for wind would have amounted to €2.3/MWh. That same simulation estimated that balancing costs for wind could be reduced to €0.8/MWh if wind forecasts could be updated two hours before delivery (Holtinen 2004). Since the launch of a common balancing market in Nordpool, most of the regulation has been from Norway and Sweden, with the lowest bids from the large hydro plants.

The Elspot market is complimented by the Elbas, a market where there is continuous trading of hourly contracts up until the hour before the set delivery of the electricity, assuming there are willing buyers and sellers. The trading can range from one hour prior to the set delivery time to the end of the next twenty-four hour period (Nordpool 2005). However, only Finland, Sweden and eastern Denmark participate in Elbas, and reportedly, the volumes traded in Elbas are not large (Holtinen 2005b).

6.0 Balancing Impacts of Wind Power

Primary regulation assists with the short-term, minute-to-minute balancing and control of the power system frequency. Primary regulation must be available within seconds and is typically done by synchronous generators that will increase production when frequency drops or reduce production when frequency increases. Secondary regulation takes over for primary regulation 10 to 30 minutes later, freeing up capacity to be used as primary regulation.

The UCTE and Nordel systems have differing demand and production balancing methods. In the Nordel system, for any disturbance to the system, the first half of the primary regulation is activated within five seconds of the disturbance, followed by the other half within 30 seconds. The primary regulation must be able to cover a loss of up to 1,100 MW of production and 100 MW of the load of self regulation. Also, the Nordel system requires frequency regulation reserves of 600 MW/Hz and manually activated regulating capacity, up or down, to be activated within 10 to 15 minutes. In the UCTE area, the primary regulation in UCTE must be activated within 30 seconds of the disturbance and can cover the loss of 3,000 MW of production and a specified degree of self-regulation of load. In Energinet.dk, the primary regulation capacity is 35 MW. The amount of required primary and secondary regulation capacity in western Denmark has not been changed, despite the increase in wind power from 0% to over 20% (see Figure 5).

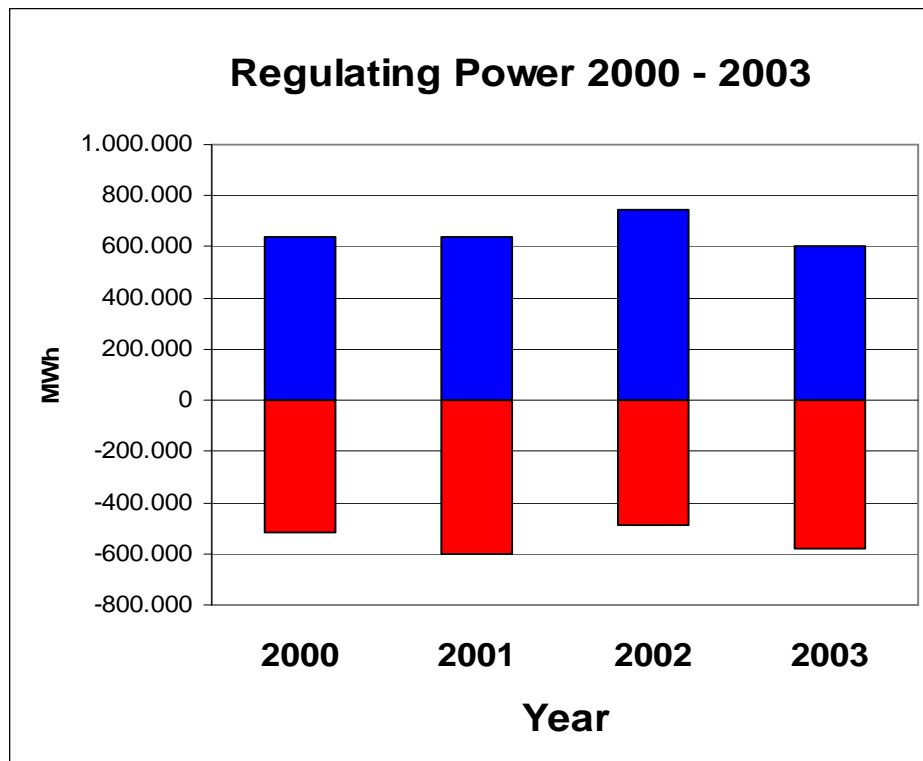


Figure 5. Regulating power in Western Denmark, 2000-2003

Source: Agersbaek, Gitte. "Wind Integration in Western Denmark." Minneapolis, Minnesota: Presentation for the Utility Wind Interest Group's Wind Integration and Interconnection Workshop, April 14, 2005

Until the end of 2002, each country in Nordpool had its own balancing market, with Denmark having two such markets. Until the end of 2002, the TSOs in Denmark managed the balancing requirements of wind generators. In 2003, Nordpool launched a common balancing market. Every TSO takes balancing bids, and Nordpool combines them in a common resource stack. If transmission congestion occurs, only the regulation bids from within the country can be used. The owners of wind projects supplying the spot market have to handle the financial requirements of balancing power, either by paying the TSOs to do it or contracting with another company. In Denmark, most wind companies supplying the spot market have formed a cooperative to take care of spot market trading and balancing.

For 2005, regulation costs averaged 0.7 Euro cents per kWh for up regulation, and 0.8 Euro cents per kWh for down regulation. The costs for regulation due to wind power averaged 0.2 Euro cents per kWh. These costs could be lowered further if wind generators could provide updated schedules closer to the operating hour than the 12-36 hour advance scheduling requires in place currently (Morthorst 2006).

7.0 Wind Forecasting

Denmark is one of the pioneers in developing and deploying wind forecasts. That said, wind forecasting errors are significant, especially the further away from the time of actual generation. About 90% of wind generation can be predicted 1 hour ahead, 70% nine hours ahead, and 50% 36 hours ahead (Holttinen 2004). The wind power prediction tool (WPPT) is used to formulate a forecast for wind production in Western Denmark. The WPPT model divides the Western Denmark region into subareas, each with a reference wind project, local measurements of climate variables, and metrological forecasts of wind speed and wind direction are used to develop a wind power forecast. The power prediction for each subarea is scaled to cover all wind turbines, forming the total wind forecast.

In Denmark, the mean absolute error by installed capacity for wind forecasting is typically between 8% and 9%, which is equivalent to a 38% of yearly production miscalculation for market operations (Eriksen and Hilger 2005). The wind forecast errors resulted in added regulation costs of \$68 million DKK in 2002, or 0.02 DKK per kWh of wind power (equivalent to \$11.68 million, or \$0.03/kWh, as of November 2006).

Forecasting the actual wind production is difficult in Denmark because most of the weather fronts pass through the Norwegian mountain range before hitting Denmark. The Norwegian mountains either push the weather system to the north, or down to Denmark in the south (Agersbaek 2005). Another contribution is the relatively low quality metrological data, in part because the exact value for regions and time have not been as necessary for other applications. An accuracy of +/- 2 m/s and +/- 2 hours has generally been enough, but can result in large errors for wind (Holttinen 2005a).

Denmark is looking at "ensemble forecasting," i.e., using 25 different wind forecasts and determining an average and distribution for the forecasts. This could improve the forecast accuracy by about 20% (Eriksen and Hilger 2005). Combining wind forecasts for eastern and western Denmark would also reduce forecast errors by 9%, according to one market simulation (Holttinen 2005a).

8.0 Exporting Wind Generation and Transmission Congestion

At times, hourly wind production can exceed 100% of consumption (see Figure 6). In these cases, the wind generation must be exported or curtailed. This situation is also aggravated by Nordpool's inability to set a negative price, something Nordpool was going to try to rectify (International Energy Agency 2005a).

Wind may lower the market price in western Denmark, sometimes as low as zero for a number of hours. For 2003, there were 84 hours where the price was zero (Eltra 2004a). Such a situation can occur even if generation is exported but supply is still more than demand. Effectively, western Denmark is separated from the rest of Nordpool and constitutes a separate pricing area. Conventional power plants have to reduce their production until the supply and demand balance is restored (Ackerman and Morthorst 2005). Overall, wind generation reduced spot prices by 12-14% in Western Denmark in 2005 (Morthorst 2006).

Figure 7 shows net exports of electricity production in Denmark from 1990 through 2004 (Agersbaek 2005). Between 2001 and 2003, Eltra, the TSO for Western Denmark until 2005, has paid between 136 and 454 million DKK annually for transmission congestion costs, including charges from Germany. A representative of Eltra stated that "wind power to a very large extent determines the dependence of Western Denmark on other countries" and believes this will continue, unless wind power is required to contribute regulation (Eltra 2004a). Eltra was interested in expanding its interconnection with Germany to 1,500 MW in either direction, as opposed to 800 MW northbound and 1,200 MW southbound. Ironically, Germany's rapid growth of wind within its borders, particularly in northern Germany, could hamper transmission capability between Denmark and Germany to a few hundred megawatts.

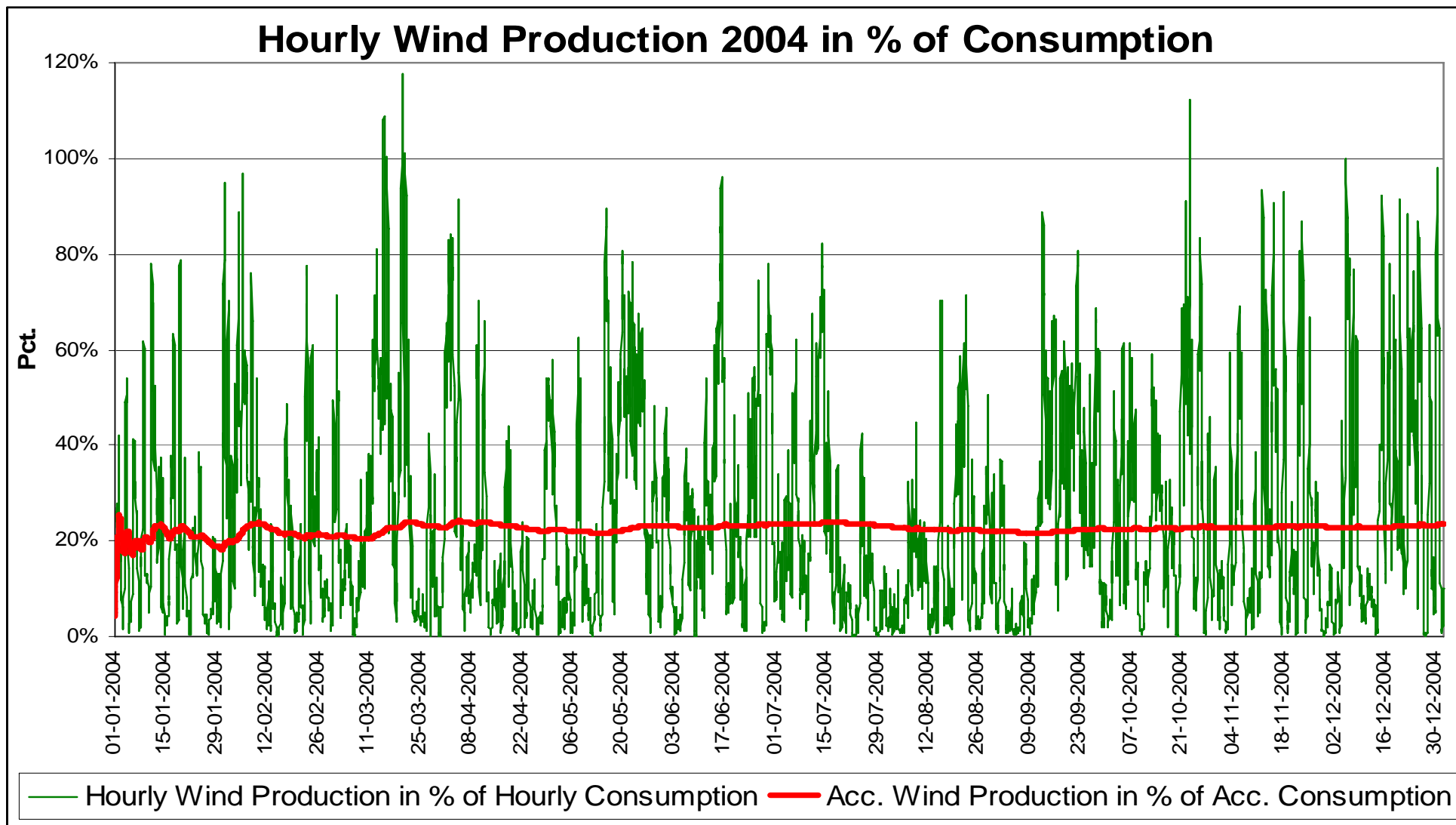


Figure 6. Hourly wind production in Western Denmark in % of consumption

Source: Agersbaek, Gitte. "Wind Integration in Western Denmark." Minneapolis, Minnesota: Presentation for the Utility Wind Interest Group's Wind Integration and Interconnection Workshop, April 14, 2005

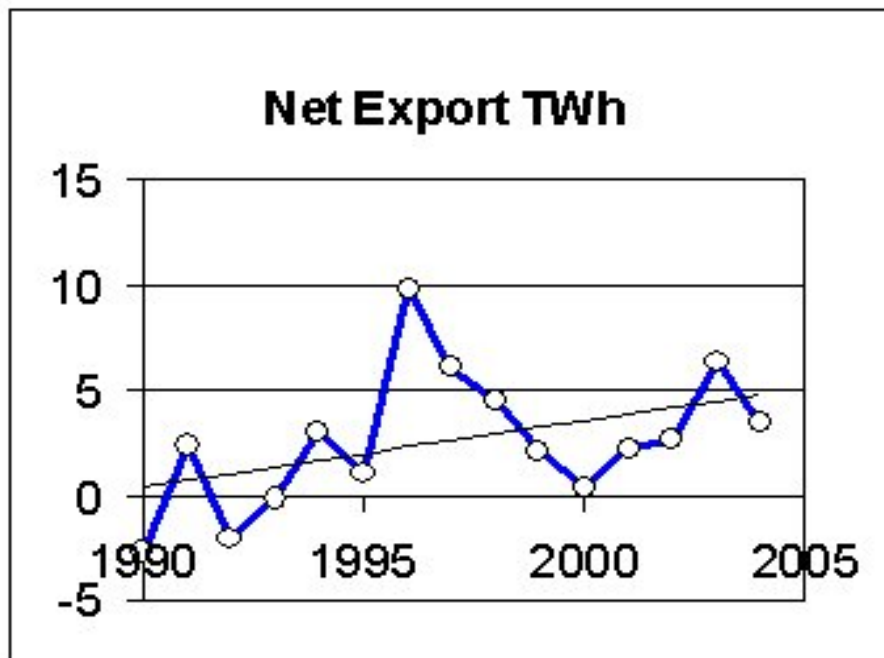


Figure 7. Net electricity exports from Denmark, 1990 – 2004

Source: Agersbaek, Gitte. "Wind Integration in Western Denmark." Minneapolis, Minnesota: Presentation for the Utility Wind Interest Group's Wind Integration and Interconnection Workshop, April 14, 2005

9.0 Interconnecting Wind Generators in Denmark

In Denmark, wind transmission and updating costs are prorated to the two network operators. The wind farm owner pays for network connections, but any necessary upgrade to the system is the obligation of the network operator (Blunden 2004). The network operator recovers the costs from all network users via transport tariffs.

Wind generators connected to the network must meet certain requirements to balance the variation of wind production on the grid system and to maintain security and reliability. For interconnections over 100 kilovolts, the wind generator must be able to survive voltage faults of up to 100 milliseconds and be able to resume production once the fault has been disconnected and voltage returns. In addition, wind generators must be able to reduce output to between 0 and 20% within seconds, of the TSO's request. Denmark also allows for the curtailment of wind generator and requires wind generators to limit power output changes, both at the TSO's direction. High wind speeds must not result in the simultaneous shutdown of all wind turbines and wind generators must provide the reasons for all wind project shutdowns to the TSO. Wind turbines must also meet standards for voltage quality.

For wind generators that are under 100 kilovolts, there are also requirements for connection to the network. Since the smaller generators are typically connected to the distribution system, they must be able to balance the local requirements for the security of the supply, mainly voltage quality, with the overall system requirements such as fault-ride through and frequency control (Eriksen and Hilger 2005). The wind generator must be able to limit production between 20% and 100% of its rated power and control the regulating speed for production externally in a range from 10% to 100% of rated power per minute. The turbine regulation is required to have the ability to change the frequency from independent to dependent control and make changes based on the grid frequency. In addition, the reactive power must lie within a specific control band over a five minute average, and abnormal voltages and frequencies must not result in reduction of the production from the generator by more than 15%. The generator must disconnect if the voltage or frequency deviates from the operational settings, but it must not disconnect during the following grid fault conditions: 1) a three-phase short circuit lasting 100 milliseconds, 2) a two-phase short circuit lasting 100 milliseconds followed by a new short circuit from 300 to 500 milliseconds. Also, the wind generator must have sufficient capacity to withstand at least two, two-phase short circuits in two minutes and at least two three-phase short circuits in two minutes, along with having sufficient reserves to withstand six two-phase short circuits in five minute intervals and six three-phase short circuits in five minute intervals. All wind generators connected to the grid must be able to connect and disconnect all operations externally (Eltra 2003b).

10.0 Conclusion

In Denmark, a significant amount of wind has been integrated onto the electricity system and there are plans for additional wind power. The Denmark government has set a target of integration of wind power production reaching levels high enough to supply 50% of the country's energy. Currently the internal transmission system and interconnected transmission system with their neighbors is maintained through a system of wind forecasting and the use of operating reserves and international trading to balance the system. However, transmission upgrades, both internally and with neighboring countries, improved wind forecasting, improved control of generation and load, and a better regulating power market, are all on Denmark's wish list for the better integration of wind.

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